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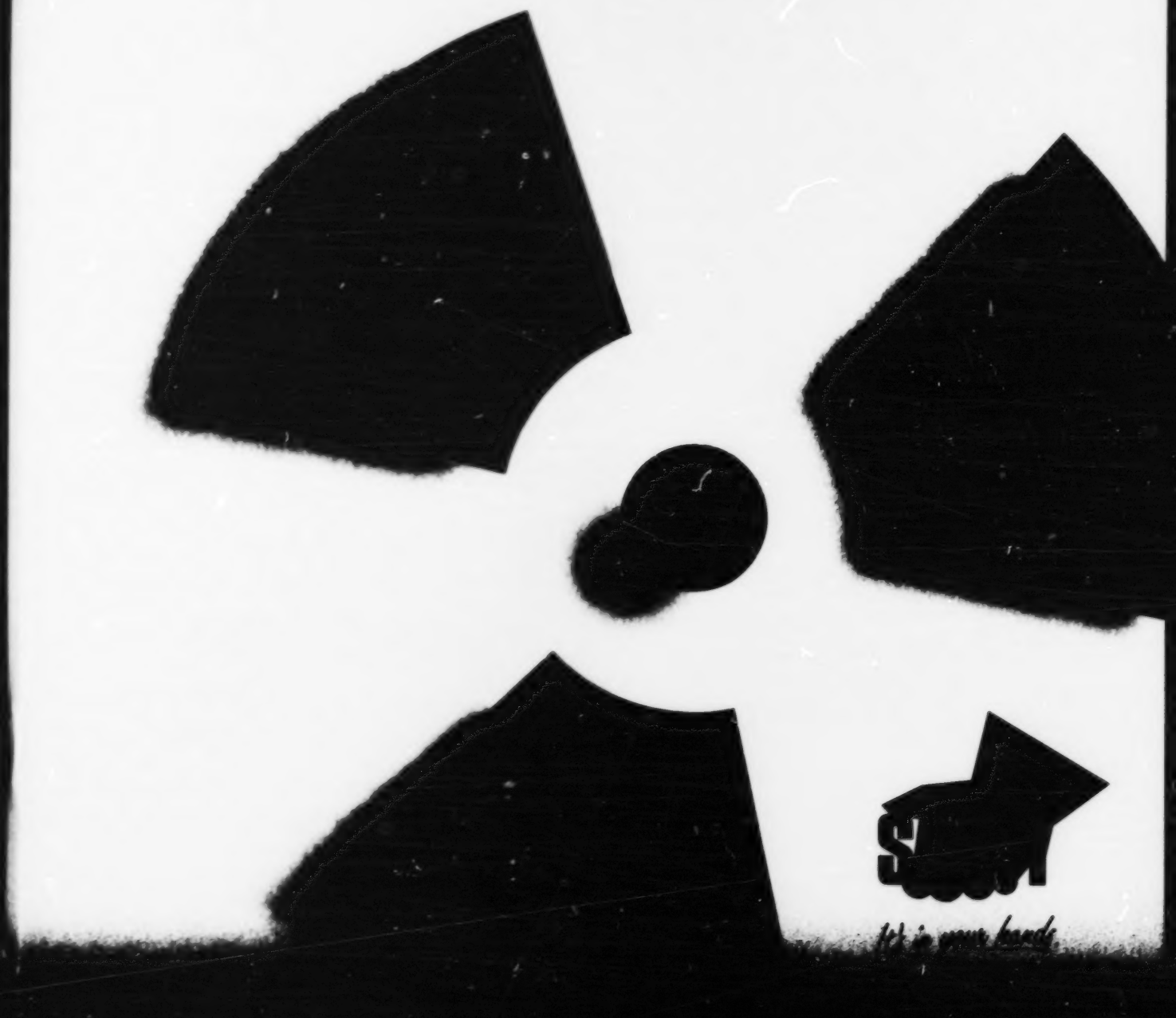
Quality Assurance in the Diagnostic X-Ray Department



Quality Assurance in the Diagnostic X-ray Department

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QUALITY ASSURANCE IN THE DIAGNOSTIC X-RAY DEPARTMENT

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Saskatchewan Human Resources, Labour and Employment

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Abstract

This report reviews x-ray quality assurance procedures which are commonly implemented in the diagnostic radiology departments of small and medium size hospitals. It has been written specifically for hospitals in Saskatchewan, and in particular, it attempts to explain the way in which responsibility for various aspects of quality assurance in the province is divided between the radiologists, the hospital administrators, the x-ray service company engineers, the Radiation Safety Unit of the Department of Human Resources, Labour and Employment, the Regional X-ray Consultants and the technologists responsible for the hospital x-ray departments. It also provides guidance notes on the establishment of a comprehensive quality assurance program in a small or medium size hospital.

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Preface

A first draft of this review of quality assurance procedures appropriate for the diagnostic x-ray department of small hospitals was prepared late in 1984, and was circulated widely throughout the province with a request for detailed comments.

Responses were subsequently received from individuals associated with the following organizations or groups:

The Saskatchewan Radiation Health and Safety Committee
The Hospital Standards Division of the Department of Health
The schools of radiologic technology in Saskatoon and Regina
The Regional X-ray Consultants
Radiologists, X-ray Technologists and Hospital Administrators
Representative large and small hospital x-ray departments
Representatives of x-ray equipment and film supply companies

Grateful thanks are expressed to all individuals who spent considerable time and effort in preparing such comments, which were all carefully considered before the preparation of this revised copy of the report. Apart from specific technical points, the comments tended to fall into two approximately equal groups. Some respondents felt that it would be very valuable for each individual technician to have a fully comprehensive quality assurance manual written in a form that was compatible with the administrative procedures applicable to the conduct of radiology in Saskatchewan. In general, these individuals took the view that this need would not be met by books or other documents prepared outside the province. They believed that the original draft was valuable but not sufficiently comprehensive, and various suggestions were made about the inclusion of additional material felt to be of importance.

By contrast, other respondents felt that the primary need was to supply a very concise summary of the procedures felt to be most important, which would not appear intimidating to busy technologists in small hospitals where there is no integrated program in place at present.

It appears that the only way to satisfy both these widely held and to some extent, mutually incompatible requirements, is to divide the complete document into two parts so that part A comprises realistic guidance on the most essential aspects of quality assurance which has been drafted explicitly to meet the needs of small departments where a formal quality assurance program has so far not been established; and part B comprises a reference manual giving additional information about more specialized aspects of quality assurance, intended to provide supporting material that will be of value to departments where a full quality assurance program is already in place. With this format, the two parts could be either completely independent documents, or successive sections of one single comprehensive manual. The latter

might be criticized on the grounds that the size of the final complete document would still be intimidating to a busy technologist in a small hospital; conversely however, with two separate parts, there would inevitably be redundancy where much of the material prepared for part A had to be repeated in part B, and there would be less likelihood of those technicians primarily concerned with the basic requirements covered in part A being aware of material relevant to their needs if this was only included in a separate second part. The present document, therefore, comprises both parts in a single manual with references in part A to relevant supporting material included in part B. User comments on whether this arrangement is acceptable, or whether two completely separate independent documents would be preferred, will be welcomed by the Radiation Safety Unit. All other criticisms or comments will also, of course, be greatly appreciated.

Introduction

This report constitutes a fairly comprehensive manual on x-ray quality assurance procedures appropriate to medium and small hospitals. It has been divided into two parts - Part A consists of four chapters which discuss the purpose of a quality assurance program and the essential procedures that must be in place in every hospital however small. It is intended to serve as a stand-alone document which can be used by the very small hospital planning to introduce a comprehensive quality assurance program for the first time. For such centres, Part B can be regarded as providing back-up material which can be referred to as necessary if any specific problems not discussed in Part A are encountered. This arrangement should be particularly appropriate for departments which have a technologist sharing responsibility for both x-ray and laboratory procedures.

In somewhat larger departments which have a dedicated x-ray technologist who is a registered member of CAMRT, a more comprehensive quality assurance program may be expected, particularly at the time of hospital accreditation surveys. For these departments, the two parts of this manual will together constitute a fairly comprehensive review of the quality assurance procedures that are now commonly expected to be implemented by medium size hospitals. They should provide a useful check list against which the features of any existing in house program can be quickly evaluated. However, it is still recommended that in those centres where there is currently no in house quality assurance program, or where this is somewhat rudimentary, every effort should be made to establish a program along the lines discussed in Part A before any detailed consideration is given to Part B of this manual.

The appendices at the end of this manual do not relate specifically to either section and are equally applicable to programs in departments of all sizes.

PART A

Chapter 1 - The Purpose of a Quality Assurance Program

Diagnostic radiology is a procedure which should be evaluated on a cost benefit basis. All exposures to ionizing radiation are potentially harmful - every x-ray, therefore, has its cost in terms of possible long term adverse health effects. Generally speaking, the diagnostic value of the procedure to the patient concerned (whether the diagnosis is positive or negative) is so much greater than any associated detriment that little attention is paid to the existence of the latter. Nevertheless, when one considers a large population, it becomes inevitable that some individuals receiving diagnostic x-ray examinations will eventually die of a radiation induced cancer. A 1977 study in the U.S.A. estimated the average annual radiation dose to the bone marrow from medical and dental x-ray procedures at about 1 mSv/year (100 mrad/y, roughly equal to average natural background radiation). In a population of a million, which is roughly the population of Saskatchewan, the most reliable estimates of radiation risks suggest that this would eventually lead to between ten and twenty cases of radiation induced cancer or leukemia.

This represents a fairly insignificant level of risk for any of the individuals concerned but nevertheless has extremely serious consequences for those few people who are actually affected. Obviously, it is desirable for diagnostic x-ray procedures to be carried out in a way which both maximizes the benefit to the patient and minimizes the associated radiation detriment. Any complete set of procedures directed towards this end have become generally known as a quality assurance program, and during the past decade in all parts of the world increasing attention has been paid to the importance of introducing such a program and providing adequate resources for it.

A full quality assurance program will ensure that radiographs are only prescribed when they are medically justified, that the radiographic procedure results in a good image of high diagnostic value while keeping the radiation exposure of the patient to a minimum, and that the radiographic image is finally evaluated by skilled and experienced physicians so that it yields the maximum possible benefit to the patient. It also incorporates procedures designed to eliminate unnecessary radiation exposure of either other patients or hospital staff. It, therefore, necessarily involves contributions from many different individuals. Although the most important of these contributions come from the radiologists and x-ray technologists other essential elements of a complete quality assurance program are provided by the x-ray company service personnel and by consultant radiation physicists. The purpose of this manual is to describe the non-medical parts of a full quality assurance program as it should be carried out in a typical small hospital with perhaps one x-ray room; as well as to

explain in more detail which parts of this program are the responsibility of the Department of Human Resources, Labour and Employment, Radiation Safety Unit, and which parts remain the sole responsibility of the senior x-ray technologist.

Although quality assurance is far from a new concept, and many progressive centres have had highly efficient Q.A. programs in place for many years, their importance has very recently been underlined in this country by the emphasis being placed upon them during hospital assessments carried out by the Canadian Centre for Hospital Accreditation. The 1983 guide to accreditation requirements is discussed in greater detail in Appendix (d). A secondary purpose of these notes is therefore to provide guidance for any small hospitals which may be preparing to apply for accreditation for the first time. The type of program described in part A of this manual represents a minimum which should be implemented in every hospital applying for accreditation, while the additional material described in part B should be sufficient to design a program that is fully adequate to satisfy the requirements of any assessors acting on behalf of the CCHA.

An additional benefit of a Q.A. program which many hospital administrators find surprising is that there is usually an associated reduction in the overall cost of operation of the radiology department. X-ray film is an expensive commodity and well designed Q.A. programs have been repeatedly shown to result in reductions of running costs for the department which, over the long haul, are larger than the actual costs of introducing and operating the Q.A. program itself. This is discussed in more detail in Appendix (c) of this report.

PART A

Chapter 2 - The Shielding of X-ray Rooms

When any permanent x-ray installation is first brought into use a full monitoring survey should always be carried out to ensure that whatever x-ray procedures are being carried out no significant x-ray exposure rate will arise in any adjacent occupied areas. Particular care should always be taken to check the shielding provided by the operator console (although this will normally only be subjected to scatter radiation as the main beam should never be directed towards the control unit).

The results of such a survey must be carefully recorded and placed on file. Once this has been done, repeat surveys can be much more perfunctory as deterioration of the protection provided is unusual. Regular checks need to be made round the edges of the operator's lead glass window - occasionally a lead sheet will creep away from the edge of the glass. Apart from this, full repeat surveys will probably only be required as a result of a substantial change in the work load on which the plans for the facility were based, or a change in the equipment which leads to x-ray beams being angled in different directions to those used previously, or to a significant increase in the maximum kilovoltages being used. Since full radiation monitoring surveys are frequently not repeated on a routine basis, it is particularly necessary to ensure that they are carried out thoroughly and consider for example the possibility of significant amounts of radiation penetrating through the ceiling or floor of the x-ray room. Part of the quality assurance program should always include a review of any changes which might make another full monitoring survey required. For example, conversion of a storage cupboard adjacent to an x-ray room to a regularly occupied space might lead to the need for additional lead shielding. Similarly, a basement area underneath an x-ray room sometimes becomes an occupied area for the first time many years after the x-ray equipment was installed, or a shrubbery outside an x-ray room may be converted into a parking area in which the space designated for one vehicle is directly in line with the x-ray beam used for chest radiographs.

Another important question is the adequacy of shielding of stocks of unused x-ray film. Sometimes a change to a faster brand of film may result in a perceptable increase in the base plus fog density, either because radiation is penetrating the film storage bin, or because loaded cassettes are not being stored in a completely radiation free area.

This is the part of the complete x-ray quality assurance program to which the contribution of the Radiation Health Officers of the Department of Human Resources, Labour and Employment is particularly important, although, of course, the responsibility for providing adequate shielding remains with the hospital administration.

Part A

Chapter 3 - Establishing a Quality Assurance Program in a very small Hospital

When a conscious decision to establish an x-ray quality assurance program is taken by a small hospital, it is important to evaluate the existing work practices and to recognize that many of these probably already constitute a significant part of a full quality assurance program. The key elements of a complete program must include:

a) Establishing and updating as required, a comprehensive technique chart covering all the procedures normally undertaken by the department in question.
b) Ensuring that there is a regular program for evaluating the performance of all the major items of x-ray equipment being used by the department.
c) Developing stock control procedures which will ensure that films and chemicals are used sequentially in the order in which they were delivered; and that deliveries are never sufficiently large to cause any stock to deteriorate significantly before it is used.
d) Ensuring effective control of all film processing to ensure that this remains completely consistent; and that processing faults do not result in faulty stock or malfunctioning of equipment being suspected.
e) Carrying out regular routine checks on protective equipment, such as the radiographic testing of lead aprons and gauntlets, and maintaining conscientious participation in the Bureau of Radiation and Medical Devices (BRMD) personnel monitoring service.
f) Documentation of all relevant quality assurance procedures in an appropriate in-house file and ensuring that any departures from the normal or expected operating conditions are promptly followed up with the appropriate individuals or organizations (eg. x-ray service companies, representatives of film manufacturers, Regional X-ray Consultants or Radiation Health Officers attached to the Department of Human Resources, Labour and Employment).

To the technologist or administrator, planning to establish a formal quality assurance program for the first time, this last requirement is the key one. There must be a comprehensive quality assurance file for each x-ray room and this must be in sufficient detail to demonstrate that the various component parts of the program outlined above are all in place. Generally, every department will already have an acceptable technique chart. The quality assurance file should indicate any procedures for which techniques appear to be sub-optimum and steps should then be taken to update the chart, if necessary, in consultation with the appropriate regional x-ray consultant. Proper evaluation of the performance of x-ray equipment requires sophisticated instrumentation not readily available to small local hospitals. It can, therefore, be assumed that this will be the primary responsibility of established provincial programs such as the SPM (safety and preventative maintenance) program

and the radiation safety inspections carried out by Radiation Health Officers attached to the Department of Human Resources, Labour and Employment, Radiation Safety Unit. At local level, it remains important only to document any records of tests carried out on the equipment through the two programs referred to above (this documentation should include the reference radiographs of its resolution test phantom which are now normally always left with x-ray departments at the time of the Department of Human Resources, Labour and Employment inspections); and of any equipment related problems that may have been encountered by the department concerned and brought to the attention of one of these outside agencies.

All radiographic technicians should have been trained not only to appreciate the importance of, but also to implement procedures for effective stock control; monitoring of personal radiation doses and routinely radiographing all protective lead aprons or gauntlets. These aspects of proper quality assurance should, therefore, already be in place in all hospitals and the only additional requirement likely to arise is the need for proper documentation of these procedures.

The principal area where a minimal quality assurance program in a very small hospital is likely to require the introduction of additional test procedures is, therefore, the adequate control of film processing procedures. This is an ongoing process which certainly involves testing on a daily basis and may require immediate attention at any time, for example, following a variation in the temperature of incoming water to the department. Only experience will dictate what routine procedures are appropriate in each centre but careful monitoring of developer temperature is always essential both with automatic and manual processing. Thermostatic mixing valves are apt to be temperamental, particularly in hard water districts where lime deposits may occur within the valve. An ongoing check of their performance should always be made. At least once a week, the valve should be turned from one extreme setting to the other and operated for a few minutes at both extremes. This minimizes the build-up of lime within the valve alongside the point to which the control element is normally set.

Ideally, every x-ray department should have a sensitometer available for giving a controlled visible light exposure to a fresh x-ray film, which can then be processed and compared with similar films exposed on a previous occasion. This should be done on a daily basis before radiography is started in the morning. There is no other way in which an equally consistent processing performance can be ensured and efforts are being made to try and ensure that a sensitometer becomes available in every hospital in the province. Unfortunately, it is likely to be some years before they become universal issue. Where a sensitometer is not available, the department should have a standard radiograph of an appropriate test object (eg. a standard step wedge) made with a known x-ray exposure; test radiographs of the same object should be compared periodically with this standard one.

Simplified low cost sensitometers are available which are particularly convenient for ongoing monitoring of processor performance in smaller hospitals. One of these simplified designs provides three controlled exposures. The middle one is intended to produce a mid range density the value of which will indicate the speed of the film in use. The other two exposures span this mid-point density and their density difference will show the gradient of the straight line portion of the film characteristic curve (see chapter 8 for a description of the characteristic curve). Information on currently available products of this type can be obtained through the Radiation Safety Unit.

Since there are only three clearly defined areas of different density on the exposed film, it is much easier to compare sensitometer exposed films produced on a day to day basis than when using a normal multistep sensitometer. Also, a simple calibrated grey scale strip can be used for visual comparison with the sensitometer film on an ordinary viewing box, enabling reasonably precise checks to be made of variations in the performance of the processing system even when no densitometer is available. The Radiation Safety Unit would encourage wider use of this type of simple control tool by small x-ray departments.

Proper control of processing procedures depends greatly on whether manual or automatic processing is being used. There are many critical factors in development; temperature, acidity, dilution, exhaustion, etc. It is not always easy to identify which parameter is resulting in sub-optional performance. The situation is worse if there is doubt as to whether a loss of radiographic quality resulted from poor exposure control or poor processing. If only a single automatic processor is available, the department should always have dish development facilities which can be used to process one of two identical radiographs in order to evaluate the performance of the processor used for the second radiograph. The problems of assessing and correcting imperfect processing are fairly complex and are discussed in much more detail in chapters 6 and 7 of part B of this report. If necessary, the technologist in the small hospital can always call upon the help of the appropriate regional x-ray consultant to identify the reasons for sub-optional film processing and to implement corrective measures.

The essential requirement is to be able to demonstrate that procedures are in place which will ensure that any deterioration in the quality of film processing is detected at the earliest possible stage.

Where an automatic processor is being used, the quality assurance documentation should be sufficiently comprehensive to demonstrate that:

a) Daily minor cleaning and temperature checks are carried out.
b) Bi-weekly major cleaning and replenishment rate checks are carried out.
c) Monthly filter changes and checks of the pH* of the solutions are carried out.
d) Regular changes of the processing chemicals and checks of the silver recovery system are carried out.

* Using laboratory type pH test papers as described in part B of this manual.

Part A

Chapter 4 - Accreditation Requirements for very small Hospitals

The quality assurance requirements for diagnostic radiology expected to be in place before accreditation is sought will obviously vary greatly with the size of both the hospital and the department concerned. They will also include consideration of many non-technical requirements relating to the way in which the department concerned attempts to ensure the comfort and confidence of patients undergoing radiographic procedures. It is felt by the author of this report that most assessors would be satisfied as far as the technical requirements for quality assurance in very small hospitals are concerned, if the types of arrangements described in the last chapter are all in place. Nevertheless, it is suggested that some time before an accreditation survey takes place, the senior technologist could usefully read part B of this report which discusses many of the aspects of a comprehensive quality assurance program in much more detail, and consider whether any of the procedures discussed are particularly applicable to the situation in their own hospital.

When appropriate, advice on implementing any additional quality assurance procedures can always be obtained from the regional x-ray consultant or the Department of Human Resources, Labour and Employment, Radiation Health Officer who last carried out a radiation safety survey in the department.

Part B

Chapter 5 - Reject Analysis

It is possible to introduce a variety of quality assurance related procedures on a piecemeal basis until an adequate program is in place. The result of this approach is often that the benefits received through the program are not fully appreciated and that, as a result, interest in continuing the program is hard to sustain. Ideally, therefore, any centre without an effective program should first carry out evaluation studies of the type generally known as reject analysis. This requires the full cooperation of the faculty radiologist(s). It involves determining the percentage of films which are for any reason spoiled and then analyzing the reasons why they are unacceptable. The exact form of the analysis often varies from centre to centre but could, for example, be based on the categories below:

1) Film too light
2) Film too dark
3) Film does not cover the entire area of interest
4) Patient movement
5) Incorrect positioning
6) Incorrect or unsuccessful use of contrast agent
7) Other

For a smaller centre with a limited number of rejects, a simpler classification might be:

1) Films underexposed
2) Films overexposed
3) Image inadequacies

Except in large centres, where there are a very substantial number of faulty films to analyze, it is undesirable to have too many categories as the number of films in each will be too small to readily permit quantification of any improvements associated with the introduction of a quality assurance program. Standards of acceptability for radiographs vary widely but from studies carried out in a large number of centres in North America it appears that a typical reject rate in centres which follow no routine quality assurance program is at least 13%, and that once such a program has been established this drops to about 7% or less. Such an improvement will, in strict financial terms, easily offset 5% of the department's budget being allocated to quality control procedures; since the savings associated with lower reject rates do not apply only to the cost of film but also cover chemicals, wear and tear on equipment, staff time etc. Reductions in the costs of patients returning for repeat examinations and in the radiation exposure of both patients and staff are of course additional benefits associated with the quality assurance program.

If a cost-benefit study of this type is to be carried out, reject analysis should be suspended during the period in which the quality assurance program is being established in order that a fair comparison of the corresponding before and after figures can be obtained. Thus there might be, for example, a three month reject analysis before any new quality assurance procedures are introduced, followed by a year in which the complete quality assurance program is introduced and established and during which no reject analysis is carried out, and a final three month period during which the reject analysis is repeated with the program fully in place. This type of comparison is valuable for establishing on-going enthusiasm for the quality assurance program, not only within the department but in the hospital administration as well. However it must be recognized that a periodic or on-going reject analysis is an essential part of a complete quality assurance program because the corresponding retake rates will direct attention to those parts of the quality assurance program which have proved least effective, and to which further attention should be paid.

Part B

Chapter 6 - Techniques and Technique Charts

Diagnostic radiology is the science of x-ray imaging and the quality of a radiology service can only be judged on the basis of the diagnostic value of the radiographs produced. Note however that the operative words above are diagnostic value - not quality. Producing a radiograph of a better quality than is necessary for obtaining a clear and unambiguous diagnosis is of no value to the patient and may well have been detrimental as it may have resulted from the use of a higher than necessary radiation dose. This means that the film-screen combination giving the highest speed which produces acceptable radiographs must be preferred. Such combinations may be less tolerant of incorrect handling, and if so, this adds increased importance to the tighter control of radiographic procedures which should be one of the benefits of a quality assurance program.

The first necessity for ensuring this control is an accurate and comprehensive technique chart. This should indicate standard exposure conditions for each type of radiograph which is liable to be called for, together with accurate data on the modifications to these standard conditions which will be required to accommodate an infinite variety of patients of both sexes and all sizes, shapes, weights and pathological conditions. Pediatric radiology also of course brings in the age of the child as another critical parameter for evaluation. If an anatomical test phantom is available, this may be of great value in the initial stages of establishing an adequate technique chart. Since it is necessary to be able to consult a technique chart quickly and confidently there is a limit to the complexity which is practicable; for adults it will usually show a standard exposure for each procedure with appropriate modifications to one parameter (such as kV or mAs) to accommodate one inter-patient variable (such as chest thickness). Many technologists rely exclusively on simple rules of thumb or some simple correction table (such as the BIT system introduced by the Du Pont company) for this purpose. Such an approach is excellent over a limited range of patient sizes but eventually corrections to the correction table become necessary and this system is liable to break down. This is clearly shown where centres use two standard exposures for two very different sizes of patient. It will sometimes be found that if a patient halfway between the two reference sizes is considered, quite different techniques will be obtained by correcting up from the quoted figures for the small patient or by correcting down from those for the large one.

A service recently introduced by the DuPont Company might be of great value to the small centre faced with introducing or updating a technique chart. DuPont have created a computer program which will construct a complete and comprehensive technique chart if accurate exposures are determined for a few key procedures. The company representative in Saskatchewan should be able to provide further information about this service to any hospital interested in utilizing it.

One of the first uses of the reject analysis should, therefore, be to draw attention to any inadequacies in the technique chart for the centre concerned. A higher proportion of rejects for unusually heavy or light patients will typically indicate such a problem. Nevertheless, no technique chart can be better than the equipment for which it was prepared. Corrections of 2 kV in the voltage or 20% in timer setting which may be required for a particular patient will be academic if the generator voltage has already drifted by 5 kV and the timer is 40% in error. Most confusing of all for the operator is the situation where a 100 mAs exposure made using 100 mA for 1 second gives only half the radiation output of a 100 mAs exposure that was made using 500 mA for 0.2 second. Such errors are not infrequently encountered when equipment settings are not checked regularly. When this type of situation develops and remains uncorrected for very long the operator will automatically introduce arbitary subconscious corrections on the basis of personal experience. This means that when, finally, correct operation of the equipment has been restored there will be an inevitable period of confusion which may initially result in poorer quality radiographs being obtained. It is, therefore, very important that ongoing tests to identify this type of problem at a relatively early stage form part of any ongoing Q.A. program. It is also important for all x-ray technologists, particularly those working largely unsupported in small centres with only one x-ray room, to become sensitive to the onset of such problems and to have ready access to radiation physicists capable of checking out the performance of the equipment in question immediately if any difficulties arise.

Part B

Chapter 7 - Films, Cassettes, Screens and Darkrooms

The need for the fastest possible film-screen combination has already been stressed - however other considerations arise in some instances. For example films designed for use with rare earth screens are intended for automatic processors and are not readily processed manually. Also some older x-ray generators may not permit the very short x-ray exposures that rare earth systems may require. The introduction of these systems may then need to be synchronized with readjustment of the tube currents to half their previous settings (eg. 50, 100 and 150 mA instead of 100, 200 and 300 mA). Another problem which may be encountered with rare earth systems is that the fluorescence coating on some of the screens initially supplied were not so securely bound to the base as with the older types of screen. Consequently periodic cleaning may have resulted in the screens becoming very patchy and needing to be replaced. Unfortunately, rare earth screens do not fluoresce as strongly in ultra-violet light as calcium tungstate or similar screens. It is, therefore, less easy to detect patchy screens by the traditional method of examining them with a 'black' (U.V.) light. One alternative is to use an x-ray beam to fluoresce the screen.

In general a film screen combination has been carefully balanced by the manufacturer so that the film is dye sensitized to respond most strongly to the wave lengths of the light emitted by the recommended screens. Although some mixed systems may respond well it must always be recognized that the use of films and screens supplied by different manufacturers may not be satisfactory. Another aspect of mixing is the use of different types of either film or screen in the same department. In general this must be discouraged, although if cassettes of a certain size are used only for specific classes of examination there should be little risk of confusion. It is always undesirable for centres to have available cassettes of the same size which contain different film screen combinations. Even if these have the same nominal speed their radiographic properties are likely to differ and the use of such a mixed system will then inevitably lead to confusion.

Another important question is whether the safelight is appropriate for both types of film in use. As with screens a safelight is normally balanced by the manufacturer for use with a specific type of film. The safety of a safelight and the light tightness of the darkroom door are demonstrated by a consistently low photographic density in unexposed parts of a film. This density should not exceed 0.20, but values above 0.30 are occasionally encountered. A high base plus fog density as it is called may not only be due to direct exposure of the film to either light or radiation but also to the use of very old films or to faulty processing. A test which will help identify the cause of this fault is described in the section of this report dealing with processing.

A full quality assurance program will incorporate periodic tests of all cassettes to determine if they are no longer light tight, if the fluorescence coatings on the screens have deteriorated or become patchy, or if film-screen contact is not maintained in the loaded cassette; it will also include a check to ensure that the film storage bin is adequately shielded and that films are not being affected by any scattered radiation before they are used. Finally the possibility of light leaking into the film storage bin when the general darkroom lights are on will also be investigated.

Darkroom problems associated with inadequate temperature or humidity control also often arise. If the darkroom is not adequately heated it may be difficult to maintain the temperature of the processing solutions in winter. More intractable is the problem of an excessively high darkroom temperature in summer. In such cases it is undesirable to operate a film drying cabinet inside the darkroom itself. Serious, but fortunately fairly rare, problems arise when the darkroom itself abuts another room such as the laundry, where very large temperature variations are inevitable. It is essential for administrators and hospital architects to be aware of the fact that in such instances it may be virtually impossible to achieve consistent quality radiography.

Static electrical discharges under very dry conditions are always liable to result in spurious marks on processed films. To avoid them, humidity must be controlled during a dry season and both cassettes and screens should be cleaned periodically using a specially treated anti-static cloth.

It should be possible to maintain the ambient temperature in the darkroom within the range 18° C - 20° C, and the relative humidity within the range 40% - 60%, throughout the year.

Part B

Chapter 8 - Fundamental Principles of Sensitometry

The largest contribution to poor quality control is usually associated with erratic film processing. Development of x-ray films must be carried out in accordance with the manufacturers recommendations for time and temperature. Usually a limited range of temperatures is acceptable so long as the development time is corrected to compensate for any difference between the actual and optimum development temperatures. Manufacturers data then includes a table of acceptable time-temperature combinations which can be followed. It must however be recognized that this acceptable temperature range is strictly limited and, in the case of double coated emulsions, is very small indeed. Changes in processing temperature will alter the relative contributions of the two coatings to the final image and will, therefore, inevitably affect the radiographic characteristics of this final image. Today the vast majority of x-ray film is developed in automatic processors where the transit time of the film through the developing tank cannot be easily modified to correct for any change in processing temperature. Consequently the manufacturer has little inducement to provide a product which is capable of being successfully developed over a wide range of temperatures.

Developing solutions oxydize and must be kept covered as much as possible when not in use. They must also be replenished or replaced in strict accordance with the manufacturers recommendations. The pH (alkalinity) of the developer solution is particularly important - a small amount of acid fixing solution splashed into a tank of developer will almost certainly substantially reduce its activity. If complete mixing does not occur it will also lead to patchy development.

In manual development agitation is another important parameter. Continuous agitation can lead to proper development being completed in about 60% of the time necessary with a minimum of intermittent agitation. Optimum agitation requirements for manual processing of different types of film vary significantly. Each hospital is advised to consult the manufacturer and obtain specific recommendations relating to the brand of film which is actually being used. In addition, incorrect solution level in the tanks can lead to cross contamination of the processing solutions. However careful the operator may be, residual differences in time, temperature and rate of agitation, are likely to result in greater variability of development than with an automatic processor maintained in optimum condition.

By contrast a poorly maintained automatic processor is likely to result in very erratic processing. Uneven condition of the surface of the rollers readily leads to patchy development, streaks, erratic transit times and similar problems. Inadequate temperature control or failure to replenish solutions at the correct time usually lead to totally unacceptable radiographic quality. For consistent quality with automatic processors it is imperative that the manufacturers maintenance schedule is scrupulously followed.

Sensitometry provides the ideal method of assessing the effectiveness of quality control procedures used in film processing. The typical relationship between the photographic density of a film and the light or radiation exposure which it has received is shown on Figure 1 and is known as the H & D (Hurter & Driffield) curve for the emulsion. Essentially it consists of three parts, a toe covering densities up to about 0.5 where the emulsion is relatively insensitive, a central portion between densities of about 0.5 and 2.5 where the emulsion is most sensitive and where the density increases approximately linearly with exposure, and a shoulder at densities above 2.5 where the processed film becomes very nearly opaque and, because the emulsion is almost fully developed, density changes with exposure become small. Such a curve is readily prepared if a sensitometer is available. The different exposures are given to successive strips of film by a single exposure of the film to light through a transparent grey scale, or to x-rays through an aluminum step wedge. A critical parameter is the gradient or slope of the central part of the H & D curve where it is nearly linear. In photographic theory this is known as the gamma value for the emulsion - it is equal to the difference in densities for two points where the exposures differ by a ratio of 10. Increasing development beyond the manufacturer's recommendations will lead to an excessively high gamma and probably to a loss of detail at the shoulder end of the curve. Inadequate development results in an excessively low gamma giving poor density resolution between slightly different exposures. (In general, a faster speed film will not lead to a steeper slope for the H & D curve, but will result in this curve being displaced to the left so that comparable densities are achieved for lower exposures).

Measurements of the slope of the H & D curve are not necessarily made only over the central portion which gives the gamma for the emulsion. In radiographic theory reference will be found to the toe gradient, the average gradient, the mid-point gradient, the point gradient (at any other point on the curve) and the shoulder gradient.* The mean slope of the so-called 'straight line' portion of the characteristic defined above as its 'gamma' value is, however, an excellent parameter for assessing whether development of the emulsion was optimum. For most x-ray purposes gamma values outside the range 1-1.5 are probably not compatible with optimum radiographic quality. A full x-ray quality assurance program will, therefore, include periodic assessment of processing and of the gamma value to which the film has been developed. (Note that the optimum value of the gamma will depend upon the type of film and the type of radiation used to make the exposures as well as upon the development. Characteristic curves obtained from exposure to light will be quite different to those from x-rays; and, in the x-ray case, the presence or absence of intensifying screens will also change the characteristics. Changes in the spectrum of the light or x-ray source will produce smaller changes in a characteristic curve. It is, therefore, not possible to quote a definitive optimum value for gamma, but any arbitrary change in value probably indicates a significant change in the processing).

* These terms are defined in Appendix (e).

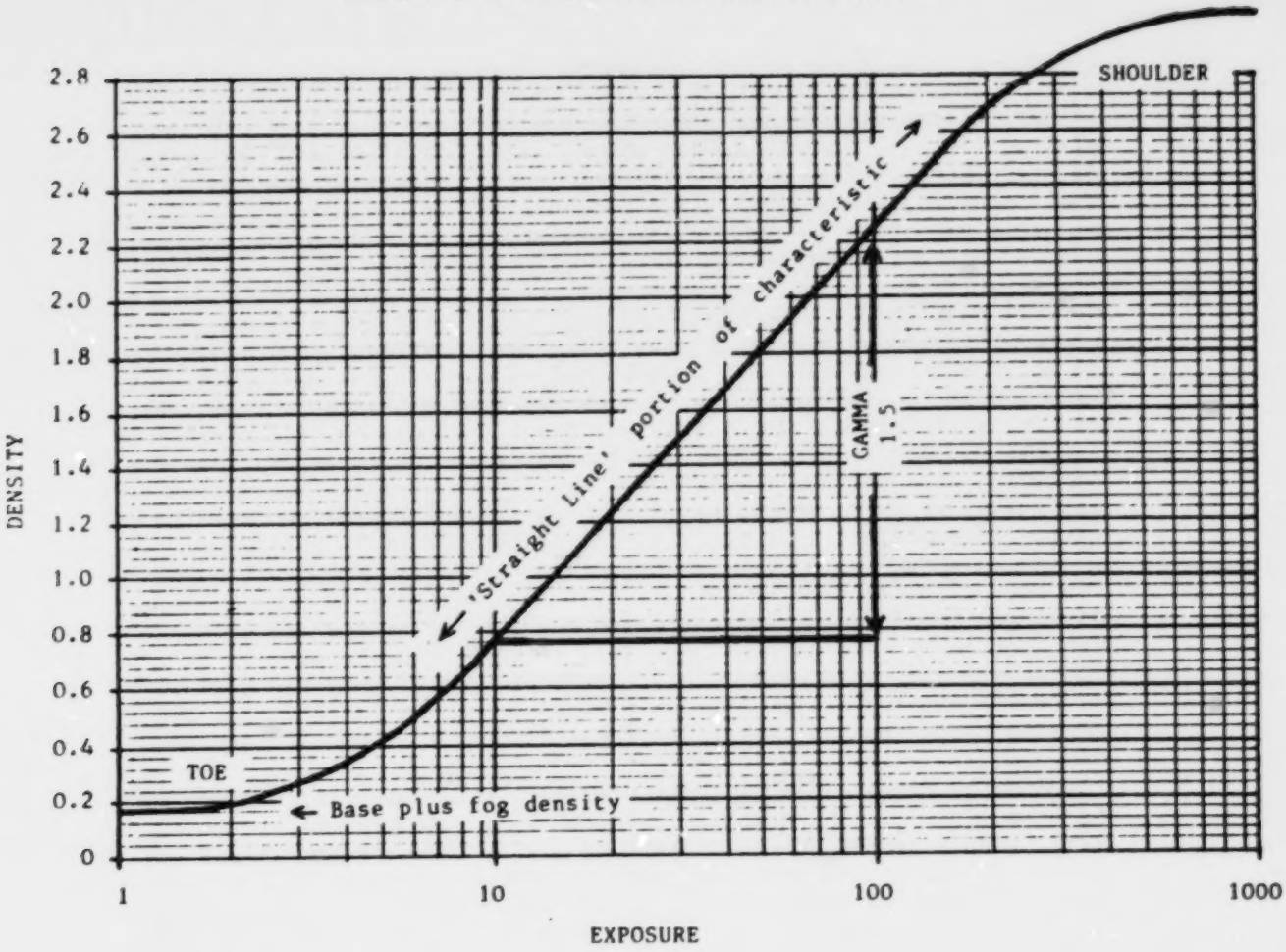
In the previous section of this report, reference was made to the need to check the darkroom safelight periodically. A common procedure for doing this is to take a strip of unexposed film, place it on the darkroom bench for a few minutes in the direct light of the safelight being used and cover half of it with a piece of card or other opaque object. If a density difference between the two halves can be observed after processing, the safelight is correctly considered to be unsafe.

However, reference to the discussion of sensitometry above and to the H & D curve shown on figure 1 indicates clearly that this is not a very sensitive test since the light from the safelight is falling onto the film at the extreme end of the curve where its sensitivity is inherently very low. A better procedure is to take a radiograph of some suitable test object, or a radiograph of no diagnostic value (for example because of patient movement), remove this from the cassette and expose half of it to the safelight in the manner described above. A difference in density due to a faulty safelight will be much more readily perceived using this modified form of test.

An alternative procedure for safelight checking is to use a new film but to pre-sensitize it with an x-ray exposure of about 2 mAs at the lowest available kilovoltage setting. It may not be possible to use this procedure with some older x-ray generators as sufficiently low x-ray exposure settings may not be obtainable from the control unit.

FIGURE 1

THE H & D CURVE FOR A PHOTOGRAPHIC EMULSION



- Base plus fog density for the above photographic emulsion is 0.18

- The toe gradient of the emulsion is the mean between:
  densities 0.25 net and 1.0 net (and above base plus fog) OR
  densities 0.43 (0.25 plus 0.18) and 1.18 (1.0 plus 0.18).

- The average gradient of the emulsion is the mean between:
  densities 0.25 net and 2.0 net (and above base plus fog).

- The mid gradient of the emulsion is the mean between:
  densities 1.0 net and 2.0 net (and above base plus fog).

- The point gradient of the emulsion is measured at any specified point.

- The shoulder gradient of the emulsion is the mean between:
  densities 2.0 net and 3.0 net (and above base plus fog).

Part B

Chapter 9 - Monitoring Film Processing

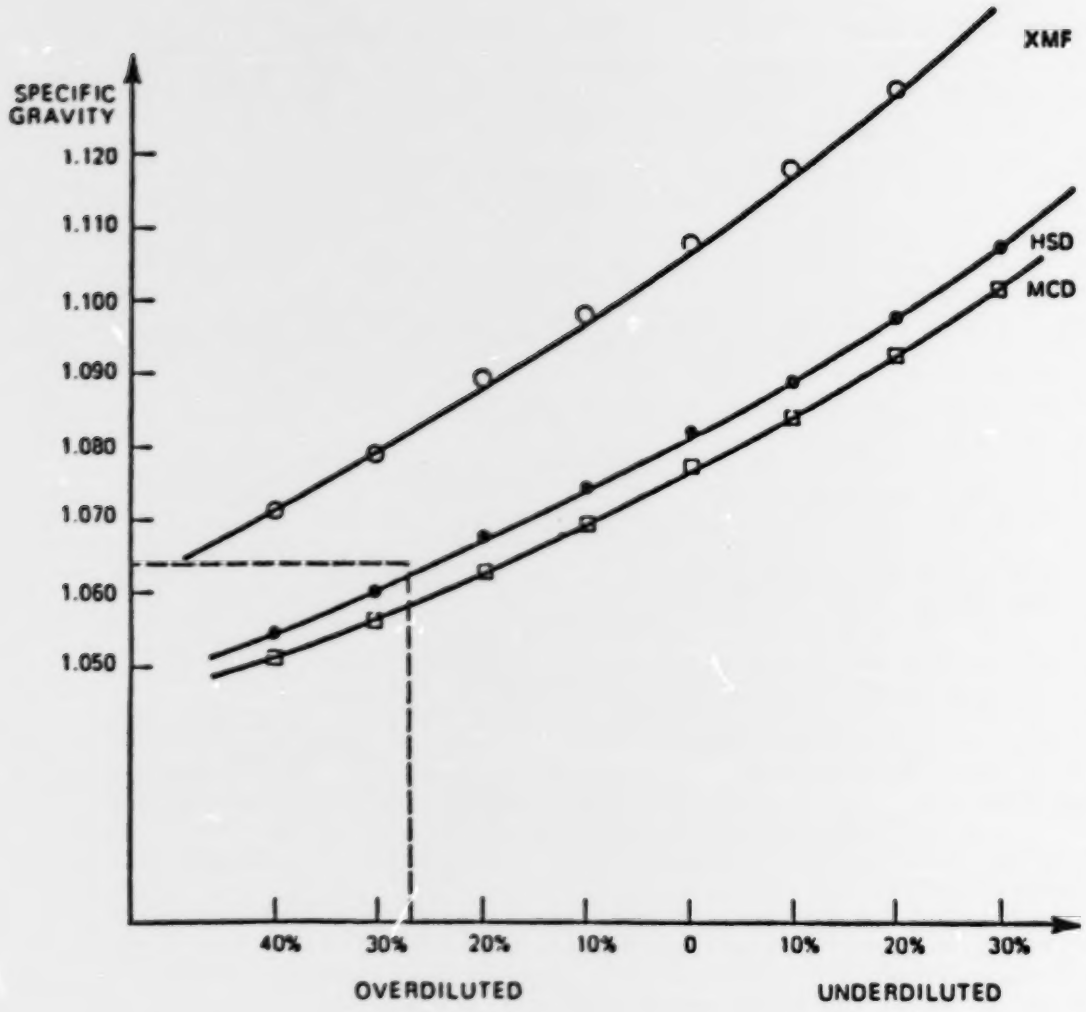
Larger centres with two or more independent film processing stations will continually compare their results and so will quickly become aware of any deterioration in the performance of a processing station. In small centres, where this is not possible, it is very important to take all possible steps to avoid a gradual deterioration in processing standards which might not be noticed for some time.

Monitoring of processing standards must start with steps to ensure proper rotation of stocks of both films and chemicals. All stock should be dated when received and, as with pharmaceuticals, a maximum storage time should be introduced - any stock not used within this time should be ruthlessly discarded. The actual time stock can be safely retained is best decided by each centre on the basis of tests, as it is extremely dependent upon storage conditions. Manufacturers quote maximum recommended storage times which should never be exceeded but these are based on ideal storage conditions and will not be applicable in all centres.

The most critical part of the actual film processing is the development. Developer temperature, concentration and alkalinity are all critical. Temperature must be checked regularly at intervals dictated by experience- the thermometer used must be calibrated periodically-either against another thermometer from the laboratory, or against a reference one obtained from the appropriate Regional Consultant. Use of a mercury thermometer in the x-ray department is strongly discouraged - should the thermometer break, it will prove difficult or impossible to clean up spilled mercury. Thermometers obtained from photographic stores or x-ray supply houses should be safe to use as they are normally alcohol filled to avoid this problem. However, where the department is equipped with an automatic processor, it is desirable to avoid using any liquid in glass thermometer because of the risk of breakage leading to glass fragments becoming embedded in the processor rollers. Only all metal dial thermometers should be used with automatic processors.

The typical pH value of x-ray developer is in the range 10.3 to 10.8. Narrow range pH test papers covering this range are readily obtained (eg. from the Cole Palmer Company or other laboratory supply house) and should be used on a routine basis. Another set of test papers covering the range 4-5.5 should also be obtained for checking the fixer - sometimes sufficient developer solution accumulates in the fixer to totally neutralize its acidity. Patchy results are then inevitable as development will be continuing during the fixing process. The main problem with the developer is maintaining a correct rate of replenishment. Even with equipment designed to do this automatically, adjustments will not remain correctly set indefinitely and constant monitoring is still necessary. Too much replenisher will lead to excessively strong developer, resulting in high contrast and high fog levels. Too little replenisher results in the developer becoming exhausted giving inadequate shadow detail and low maximum density. Overdilution of the developer with water will also

FIGURE 2



HOW TO USE THE GRAPH:

Step 1 - Measure the specific gravity of the replenisher sample at room temperature with your hydrometer.

Step 2 - Draw a horizontal line across from the measured value to the approximate curve.

Step 3 - Draw a vertical line down from this point to the dilution axis and read volume.

e.g. HSD with a S.G. of 1.064 is 27% overdiluted.

have the same effect even if very little film has been processed. The most satisfactory test procedure is to use a sensitive hydrometer (also obtainable from Cole Palmer or other laboratory supply houses) and to check at intervals to see whether the specific gravity of the developer solution has changed significantly since it was first mixed. Figure 2 is a copy of a graph provided by the DuPont company which shows how the specific gravity of their x-ray developers varies with either over or under dilution. Similar graphs are available for other products. An occasional explanation of grossly incorrect specific gravities of processing solutions is failure to appreciate that packages of chemicals supplied in Canada are normally prepared for the U.S. market, and consequently, references to gallons in the making up instructions always relate to U.S. gallons - not to Canadian imperial gallons.

A very valuable method of obtaining an ongoing assessment of film processing is to use one of the new heading machines which incorporates a photographic gray scale strip.* This effectively supplies a sensitometer control strip underneath the heading on each film used. The various density steps can be evaluated by eye when the film is on a viewing box - any significant change is fairly readily noted. If necessary, a densitometer can then be borrowed to permit more precise evaluation but the visual change in the appearance of the strip is often sufficient to indicate the probable reason for the problem.

Some technologists have successfully modified conventional heading machines to incorporate a gray scale strip about 2.5 - 3 mm wide cut from an x-ray film exposed on a sensitometer. This is an economical alternative to the purchase of a new heading machine, and the Radiation Safety Unit will be happy to assist any technologist wishing to try this approach.

Ultimately, however, where image quality deteriorates and only one film processing station is available, the smaller hospitals may have great difficulty in deciding whether the problems arise from the x-ray equipment or the film processing. A small reserve processing facility is invaluable at such times. All that is necessary is a small supply of fresh developer solution and a print developing dish from a photographic store large enough to contain the smallest films used by the centre concerned. Two identical radiographs of a step wedge or some other convenient test object are made on this size film. The first of these is developed in the conventional way, the other is dish developed with time and temperature carefully monitored, then washed and fixed in the usual way. If the first film gives a significantly inferior image, the problem is identified as one associated with processing. A fresh litre bottle of prepared developer as supplied for processing dental x-ray films, or even black and white paper prints, should be purchased occasionally by each small centre in case this type of testing becomes necessary.

* Information on currently available products of this type can be obtained through the Radiation Safety Unit.

Differences in film density may result from different temperatures at the time the film is exposed as well as from different processing temperatures - however, the exposure temperature is far less critical. The parameter of interest in this respect is the temperature sensitivity of the film-screen combination. In practice, film emulsion speed increases slowly with increasing temperature but for conventional screens the sensitivity decreases rather more sharply. This means that the overall film-screen speed drops with increasing exposure temperature. Generally, the ambient temperature in x-ray rooms is not subject to very great change and exposure correction is not required, but there may be a decrease of film-screen speed of the order of 30% if the temperature of the x-ray room rises from say 20° C to 38° C. (Conversely, industrial radiographers exposing films at or below freezing point may need to substantially reduce their normal exposures. This is not normally a problem for the medical radiographer). In the case of rare earth screens, it is important to note that the speed of the screen is virtually independent of ambient temperature. The film-screen combination, therefore, increases slightly in speed with rising temperature, purely as a result of the change in film speed. This change is not likely to be sufficiently marked to necessitate exposure compensation.

One part of a full quality assurance program is, of course, to ensure that stored radiographs will remain in good condition throughout the whole of the time they are retained on file. If processing procedures are monitored carefully along the lines indicated in this section, storage problems are most unlikely to arise. It is possible to buy stabilizing solutions which can be used to treat radiographs of teaching value that are intended for long term storage. It is also possible to obtain check kits that will test processed films for unfixed emulsion and/or residual fixer that has not been washed out of the films. However, unless unexplained rapid deterioration of filed radiographs is experienced, there should be no need for such products to be used on a regular basis.

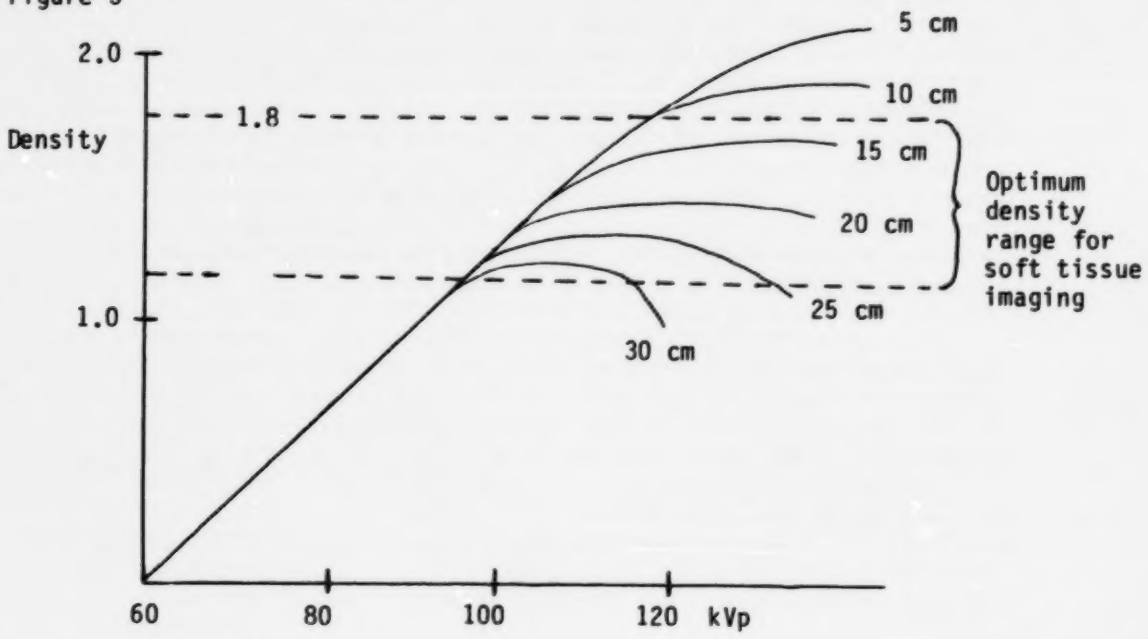
Part B

Chapter 10 - Quality Assurance for other Radiographic Equipment

The quality of a radiograph ultimately depends upon all parts of the radiographic system and a full quality assurance survey will periodically assess the functioning of every part. For example, lack of mechanical rigidity can lead to movement of the x-ray head during an exposure with resultant blurring of the radiograph obtained. A table top with excessive absorption will necessitate excessive radiation doses to the patient in order to achieve adequate exposure of the film. Similarly, it sometimes happens that the table top has a granular structure; mottling of the radiograph can then occur. Faulty bucky grid operation resulting in a visible bucky pattern on the radiograph and incorrect grid ratios are other possible causes of excessive patient exposures. Sensitivity to mains voltage fluctuations is a frequent cause of erratic radiographic quality, particularly with mobile x-ray units having an exceptionally long mains cable. Phototimers, when fitted, are a potential cause of poor quality radiographs if they are not set up correctly to ensure the optimum exposure. Daylight loading and processing systems may create another potential source for light fogging of films. Viewing boxes may have inadequate or excessive illumination levels and this may result in a tendency to produce radiographs with too low or too high an average density. Where several different viewing boxes have different colour light sources (such as daylight or warm white fluorescent tubes) or very different light intensities, it is almost impossible for the technologist concerned to maintain consistent quality radiographs. Most troublesome of all is a flashing tube which does not give a consistent illumination level. All centres should ensure that different viewing boxes have similar quality diffusing screens and that where circular fluorescent tubes are fitted in these, they are all replaced at the same time so as to maintain a uniform quality of illumination for them all. It is also important to ensure that all viewing boxes are cleaned at regular intervals.

As indicated above, a phototimer is an important part of many radiographic x-ray units. Whem correctly adjusted, it should ensure that tissue densities on most images always fall in the range 1.2 - 1.8; which is the range generally regarded as yielding the maximum diagnostic information. To check the operation of the phototimer, it is customary to use a pile of slabs of approximately tissue equivalent material (eg. paraffin wax, mix-D or lucite), each about 2.5 cm thick. Radiographs of the pile of these slabs are taken for different total thicknesses between about 5 cm and 30 cm; and for a series of different kilovoltages. The photographic density of the image is measured in each case either using a densitometer or, if this is not available, by comparison with a calibrated optical grey scale strip on a viewing box. The measured densities are then plotted against the kilovoltage for the different thickness piles. The results should form a family of curves of the type shown on figure 3.

Figure 3



It will be seen that the density of the radiograph is sub-optimal both when the kV setting is too low and when the tissue slab being radiographed is exceptionally thick. Conversely, it is excessively high for high kV settings and very thin tissue samples. However, if the phototimer is operating correctly, the radiographic densities will generally fall in the optimum range for all kilovoltage settings above about 70 kV, as long as the thickness of tissue being radiographed lies somewhere between limiting values of about 5 and 25 centimetres.

This review is being written primarily for the small centre and only brief reference will be made to fluoroscopic imaging procedures which are inherently much more complex than radiographic techniques. The key feature of the fluoroscopic system is the quality of the image intensifier tube. Where used, the quality and correct adjustment of the closed circuit T.V. imaging system is also critical. If the I.I. tube has deteriorated or the T.V. system is maladjusted, it is too easy to try and improve a poor image by turning up the intensity of the x-ray beam, often far above the level which should be necessary. The most important quality assurance procedure is to monitor the maximum x-ray beam intensity and to see that this has not been increased above the level for which the equipment was designed to operate. The imaging quality of the system must also be regularly assessed and if it shows any sign of deteriorating more sophisticated test procedures must be followed to determine which part of the system is at fault. The operation of the timer cut-off and the corresponding override switch must also be checked on a routine basis. Other tests of the equipment to be checked include:

the accuracy of the kV settings; the mAs reproducibility for different current settings; the accuracy of the illuminated field produced by the tube collimator; the operation of the spot film system and the image quality obtained with spot films; the adequacy of the curtain fitted to protect the radiologist from radiation scattered from the patient; the quality of silvering on the mirror where mirror optics are used; and perhaps most important, the operation of any automatic brightness control system. These equipment tests must be carried out regularly.

In some centres where fluoroscopic imaging equipment is available, there has been an increasing tendency to use this facility for accurate patient positioning prior to radiology. To justify this practice, the centres concerned claim a reduction in the number of repeat examinations required and an increase in patient throughput. However, it involves unnecessary radiation exposure of the patient and is, therefore, contrary to the recommendations of the International Commission on Radiological Protection. One study reported a ten-fold difference between gonad dose for SI joint radiographs made in rooms with and without fluoroscopic facilities in the same centre. The difference in the number of repeat examinations required was less than 1.5%. The Radiation Safety Unit, therefore, very strongly discourages the use of this practice as a routine procedure without specific clinical justification.

In many small hospitals there may be mobile or fluoroscopic x-ray tubes available which are only used very intermittently. In these conditions, gas will gradually be released within the x-ray tube and will eventually spoil the vacuum. Sudden use of the tube at fairly high exposure settings then leads to rapid overheating which in extreme cases may cause the tube to explode and become a significant hazard to the patient. An important part of a quality assurance program is to minimize the risk of this happening. Every month any mobile or fluoroscopic x-ray tube which has not been used should be briefly run-in. The running in process consists of making a series of x-ray exposures at gradually increasing current and voltage settings. The discharge current through the tube then mops up any gas which may have accumulated during the period the unit was out of use. During this procedure, a lead sheet can be placed over the tube collimator, or a mobile x-ray unit may be pointed up against a lead lined door or window. Nobody should remain unnecessarily close to the tube while the conditioning exposures are being made, in case of failure.

The manufacturer of the unit concerned should be able to give definitive guidance on the necessary frequency and extent of such tube conditioning procedures.

Part B

Chapter 11 - Protective Devices Required for Radiology

From the point of view of the patient the most valuable protective device is the light beam diaphragm which produces an illuminated field that should precisely indicate the area which will be included within the x-ray beam. Significant maladjustment of this illuminated field can lead to important radiosensitive tissues being exposed unnecessarily, or to the need for a repeat radiograph because the area of interest was not fully within the x-ray beam. The accuracy of alignment of this field must, therefore, be checked at regular intervals and any significant error (greater than 2.5 cm) must be corrected immediately. Smaller errors should still be corrected by the service company on their next visit. The aim should be to keep any discrepancies between the light field and the x-ray field to less than 1 cm.

Many modern x-ray units will be found to incorporate positive beam limitation (PBL) circuitry. Where this is the case, electrical feedback signals from the cassette receptacle in the patient table or chest stand result in automatic collimation. This ensures that the x-ray field is just contained within the boundaries of the cassette in use.

This system makes it almost impossible for an operator to inadvertently take a radiograph with the x-ray field larger than the chosen size of cassette. Nevertheless, it remains possible, by overriding the PBL circuitry, to collimate the beam down to restrict the image to an area significantly smaller than the chosen film size when necessary.

If a PBL system is to fulfill its intended purpose of minimizing patient doses, it is obviously important that the operator does override the automatic collimation system whenever a larger size cassette than necessary is being used. The fact that collimation is no longer an essential feature of every x-ray exposure may result in this need being overlooked. Another problem may be loss of radiographic quality resulting from excessive soft tissue scatter if automatic collimation is not overridden. This can easily occur, for example, with radiographs of the spine where good rendering of detail in the spinal processes is readily impaired by a small amount of scatter radiation; consequently, a good radiograph requires sufficient collimation to reduce the width of the x-ray field to little more than that needed for the complete imaging of the bony part of the spine. Failure to override a PBL system will irradiate a large field predominantly consisting of soft body tissues, and will result in a great deal of scattered radiation which will seriously impair the quality of the image of the bony structure.

Equipment tests on x-ray systems fitted with PBL must ensure that the automatic collimation procedure is carried out accurately, so that the x-ray field is always correctly centred within the perimeter of the cassette in use, regardless of cassette size. The tests must also ensure that when the PBL facility is overridden, the alignment of the

illuminated collimator field and the x-ray field is checked in the same way that it is with non-PBL systems.

Other protective devices which must be checked as part of a quality assurance program include aprons, gauntlets and gonad shields. Usually there will be a short (waist down) apron which can be laid over a patient to protect areas that need not be included in the radiograph, and a full length apron and gauntlet set which are available for use by a mother who may be asked to hold her child during a radiographic procedure, or by a nurse who may have to steady a senile or drunken patient. All of these will eventually deteriorate to the point where cracks or tears in the protective lining lead to serious loss of protection. They must, therefore, be radiographed periodically to check for such deterioration and replaced if necessary. In the smaller centres such radiographs should be obtained at least annually and should be retained for further reference. They may for example need to be produced during an accreditation survey. In the larger centres a six monthly check should be made. Where the gonads of patients are within, or close to, the area being radiographed, and where the half length lead apron cannot be used to protect them, they should be protected, if possible, by small gonad shields which may be made from pieces of thin lead sheet or from lead rubber strips cut from an old lead apron. The quality assurance program check list should include a space that is used to confirm the availability of such gonad shields in the designated storage place.

In a similar way, eye shields may occasionally be needed during fluoroscopic skull examinations where significant retinal doses may arise. These are, however, not likely to be required in relatively small departments. For some fluoroscopic procedures, the radiologist should wear lead glass spectacles for the same reason. Both the radiologist and any technologist present during fluoroscopic examinations must also wear full length lead aprons and, where appropriate, gauntlets. All x-ray department staff should, of course, wear BRMD personnel monitoring dosemeters - during fluoroscopic examinations these should be worn under the lead apron although, where the workload justifies it, additional extremity dosemeters may be worn outside the apron on wrists or forehead. Part of a full quality assurance program is an assessment of the justification for any radiation doses reported by the BRMD for dosemeters worn by the staff concerned. Generally, radiation doses received by staff in diagnostic x-ray departments should be very small even in relatively large centres.

Part C

Appendix (a)

Documentation of the Quality Assurance Program

A quality assurance file should be maintained in every x-ray room. All measurements or tests carried out as part of the quality assurance program should be fully documented by the individual responsible for carrying them out, and signed reports of the measurements or results of the tests should be placed on this file. Copies of all test radiographs should also be placed on this file along with any written comments that may be appropriate, and the results of periodic reject analyses form another important source of data for inclusion.

Such a file is of most value in ensuring that enthusiasm for the quality assurance program does not fade until only nominal measurements continue to be made; but it also provides full documentation that demonstrates a hospital radiology department meets the requirements of the Canadian Centre for Hospital Accreditation.

Part C

Appendix (b)

The Organization of Quality Assurance in Saskatchewan

There are four components to the technical side of the quality assurance program in Saskatchewan hospitals. These are discussed briefly below:

i) The Manufacturer's Service Department

Saskatchewan legislation requires scheduled preventative maintenance (SPM) inspections of all medical x-ray equipment by the manufacturers' service representatives. The legislation was introduced following a fatality which was caused by the mechanical failure of an x-ray unit and it ensures that the scheduled inspections fully check out the mechanical and electrical safety of the equipment in use.

Other tests are not legally required but are frequently carried out by arrangement between the Hospital Board of Management and the Company's Service Division. Thus, an SPM inspection of an x-ray unit may or may not include re-adjustment of voltage, current or timer settings or of the light beam diaphrapm, but it will always include checks to ensure that high voltage cables and counterweight systems are in good condition.

ii) The Regional X-ray Consultants

Saskatchewan hospitals have been grouped into five geographical regions each of which has a senior x-ray technologist whose duties include the responsibility to advise technicians in small hospitals on any problems relating to equipment or techniques. They do not, however, carry out the more sophisticated radiation related test procedures that are the responsibility of the Radiation Health Officers attached to the Department of Human Resources, Labour and Employment; although they will frequently alert the department to the need for such tests in a particular centre.

iii) The Radiation Safety Unit of the Department of Human Resources, Labour and Employment

This unit performs two functions - Radiation Health Officers visit every hospital periodically to carry out such tests as room monitoring surveys, measurement of radiation doses for standard x-ray procedures and of dose reproducibility, checks of kV, mA and timer settings, measurements of half value layers, checks on protective equipment, etc. These visits are relatively infrequent - small hospital visits are scheduled for only once every three years. Consequently, the unit recently introduced an additional new test procedure that can be conducted by post. This procedure involves radiographing a specially designed test phantom simultaneously with a package containing thermoluminescence dosimeters and an aluminum step wedge. The test checks the image quality, the x-ray beam intensity, the H.V.L. for the beam, the gamma to which the radiograph was processed, the base plus fog level for the film

and the accuracy of alignment of the illuminated field produced by the light beam diaphragm. It is also capable of detecting faulty bucky grid operation, excessive absorption by the table top, poor film screen contact, patchy screens and various other faults. In the past, the test was conducted only by Radiation Health Officers at the time of their routine visit to the centre concerned. Arrangements are now in hand for the new test phantom to be available in every x-ray facility and it is intended that the test will eventually be carried out by mail every six months. As copies of all radiographs of the phantom are kept on site, the technologist responsible for the department can and is encouraged to conduct periodic radiographs of the phantom (in addition to those required by the Radiation Safety Unit) and use them for internal evaluation of any deterioration in the performance of the x-ray unit in question.

iv) The Technologist in Charge of the Department

Ultimately the technologist in charge must be responsible for the full quality assurance program of the hospital. He or she must ensure that quality assurance procedures related to film processing are carried out daily on an ongoing basis, properly documented and recorded in the quality assurance file. The local technologist will also always be responsible for ensuring that more sophisticated tests carried out by other individuals for the hospital concerned are documented in the same way, that the protective clothing is radiographed periodically, that alignment of the illuminated field and the x-ray beam is checked regularly, and that further help is sought whenever appropriate from the manufacturers' service department, the Regional Consultant or the Provincial Radiation Safety Unit. These supporting organizations have an essential part to play in maintaining an adequate standard of quality assurance. Similarly, the responsible radiologist will also play a vital part through his or her involvement in periodic reject analyses, but such involvement will do little or nothing if a proper in-house program is not in place.

Part C

Appendix (c)

Cost Saving Associated with an Effective Quality Assurance Program

A 1983 publication by the National Centre for Devices and Radiological Health in the United States of America reviews the experiences of 27 major radiographic centres following the introduction of quality assurance procedures. All of them were enthusiastic about the value of the program. Where detailed financial analyses were given in these reports, they all indicated a net cost saving. The actual savings listed ranged from $4,000.00 to $50,000.00 per annum.

In Ontario quality assurance programs have been widely introduced during the past few years. Considerable concern has been expressed by the Department of Health about the potential cost of these. Consequently, a detailed study of the effect of introducing a quality assurance program in one medium size hospital was carried out. A preliminary report on this study claimed that a 32% reduction in the number of retake films was achieved in the first nine months of the program. This alone resulted in a a cost saving over the nine month period of $21,451.00.

It is clear, therefore, that budgetary restrictions cannot be used to justify delaying the introduction of proper quality assurance procedures in a hospital x-ray department.

PART C

Appendix (d)

CANADIAN CENTRE FOR HOSPITAL ACCREDITATION

Revised and Approved Board Requirements for Diagnostic Imaging Services - Radiology January 1983

Requirements with which the Radiation Safety Unit of the Department of Labour can be expected to be involved are listed below with comments by the Unit as appropriate.

Requirement	Comment
2.1 There is a written organizational plan which delineates the current responsibilities, relationships and formal lines of communication within the department and its interrelationships with other departments.	This will require formal consultations with the Department of Health, Hospital Standards Division, to delineate the exact responsibilities being undertaken by the Department of Labour with respect to quality assurance.
3.6* The services of a radiation physicist, or of a competently trained dosimetrist are available as needed for: -consultation -supervision of radiation safety procedures -participation in educational programs	Except for hospitals with Cancer Clinics, radiation physicist support for radiology departments comes exclusively from the Department of Labour. Under this requirement, we will have an ongoing responsibility to provide consultation services as required, and to participate in regular training programs.
4.* THERE SHALL BE ADEQUATE SPACE, FACILITIES, EQUIPMENT AND SUPPLIES FOR THE SAFE PERFORMANCE OF RADIOLOGY SERVICES.	Quality assurance equipment and supplies used in most hospitals are provided through the Radiation Safety Unit of the Department of Labour.
4.3 There are adequate radiographic and fluoroscopic services. - In provinces where radiology standards programs are available, these services have been assessed by the responsible body, or application has been made for such assessment. - Written records of such assessments are kept.	Quality assurance in diagnostic radiology departments is at present partly, and perhaps should be fully, assessed by Radiation Health Officers attached to the Department of Labour. In turn, our involvement will need to be assessed by CCHA.
4.4 Appropriate safety precautions are maintained against: - electrical, mechanical and radiation hazards - fire and explosion	Our present involvement in all these aspects of safety precautions should be accurately delineated through discussions with the Department of Health and fully documented.
4.5 The recommendations of the International Commission on Radiological Protection are followed.	This will require a substantially greater involvement of Department of Labour staff in training programs for hospital staff.
4.7 Calibration of equipment, and all safety measures followed, are in compliance with applicable laws and regulations.	Calibration procedures followed by the Radiation Safety Unit must be fully documented and universally followed in all hospital inspections.
8.* THERE SHALL BE PROCEDURES ESTABLISHED TO EVALUATE THE QUALITY OF RADIOLOGY SERVICES AND PERFORMANCE OF PERSONNEL.	Consultations between the Hospital Board of Management and the Radiation Safety Unit will be necessary in order to comply with this requirement.
8.2 All radiology personnel are involved in the quality assurance program.	The Radiation Safety Unit has always emphasized the necessity for this requirement. Our only involvement will be in monitoring the continuing participation of hospital personnel in all agreed procedures relating to Q.A.
8.3 The quality assurance program includes: - audit - peer review - patient care appraisal	The Radiation Safety Unit will continue to audit the entire hospital Q.A. program. Our part in this program is subject to regular peer review through meetings of a Federal/Provincial Committee in which the Radiation Safety Units of all provinces are represented.
8.4* Quality assurance activities are conducted regularly and documented.	The Radiation Safety Unit currently documents its own involvement in hospital Q.A. procedures, and proposes to monitor hospital documentation of all other "in house" procedures. The regularity will depend upon the available resources.
8.9 All documentation reference quality assurance is available for review by the surveyor(s).	The proposed procedure noted against requirement 8.4 will ensure the availability of Q.A. documentation to CCHA assessors.
* Block letters are as used in the CCHA document, underlining has been carried out in this document to draw attention to specific phrases of particular relevance.	Note that CCHA do not at this stage specify how extensive are the requirement for the services of a radiation physicist in a diagnostic radiology department. It is often accepted that a realistic target would be the equivalent of 2-3 man days for very small departments, 1 man week for most busy small departments and proportionally longer periods for larger departments; with a minimum of one man month available where digital radiographic equipment and/or CT scanners are in routine use.

Part C

Appendix (e)

Special Terms used in Sensitometry

The discussion of sensitometry in chapter 8 of this report should provide adequate information for a practicing x-ray technologist under all normal circumstances. However, it is important to appreciate that the H & D curve, or sensitometric response, of an x-ray film can vary considerably in shape depending upon how sharply the change in gradient associated with the toe and shoulder of the film characteristic curve takes place. Figure 4 illustrates two extreme forms of response curve which demonstrate the range that may be encountered in practice. Not many hospitals stock a choice of films (and in fact this is usually discouraged as a potential source of exposure errors) but it can be appreciated that these two extreme types of response have different advantages and disadvantages, and are not equally appropriate for use in different types of examination.

The shape of the response curve is, therefore, one of the factors which should be considered at the time of the initial selection of the type of film to be used. To help differentiate between the characteristics of various types of emulsion by means of simple numerical parameters, photographic chemists have introduced a number of special terms which can be found in the reference literature and which may, therefore, be encountered by the x-ray technologist in the hospital.

In order to explain these it is necessary to understand the concept that the slope or gradient of a graph can be represented by a change in the y (vertical) co-ordinate divided by the corresponding change in the x (horizontal) co-ordinate. This is shown on figure 5, both for a straight line graph and for a curve. In the case of a curve, it is possible to define the gradient at a point (ie. as measured for a very small portion of the curve), or as a mean over a specified part of the curve. It is important to note that to calculate the gradient in this way, the two axes of the graph should be scaled linearly and not logarithmically. The definition of gradient in this way is directly illustrated by the practice of expressing the gradient of a hill in a form such as 1 in 25.

Special terms used by photographic scientists include definitions of toe gradient, mid gradient, shoulder gradient, point gradient and average gradient. To obtain these from the emulsion sensitivity curve, this must be plotted with the x axis showing the logarithms of the relative exposures, not the relative exposures themselves. In this way, both x and y axes will have linear scales. Figure 6 is the same film sensitivity curve that was shown on Figure 1 in chapter 8 rescaled in this way. It is also important to appreciate that in sensitometry, the H & D curve is normally prepared by exposing the x-ray film to light as explained in chapter 8. A sensitometry curve can be prepared by x-ray exposure of a film-screen combination in a cassette but if this is done it is always necessary to specify that all the measured parameters relate to

FIGURE 4 - Examples of H & D Curves

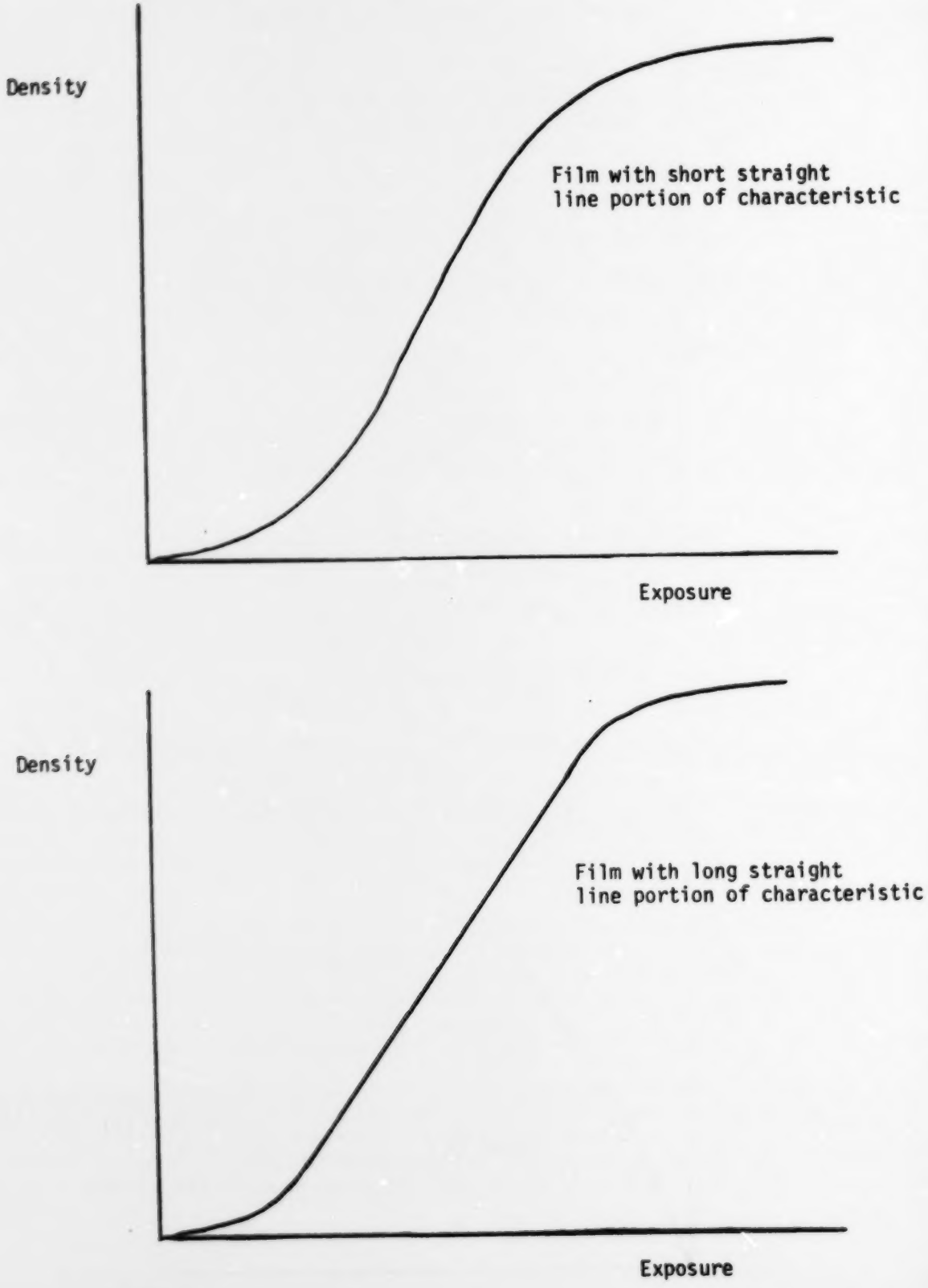
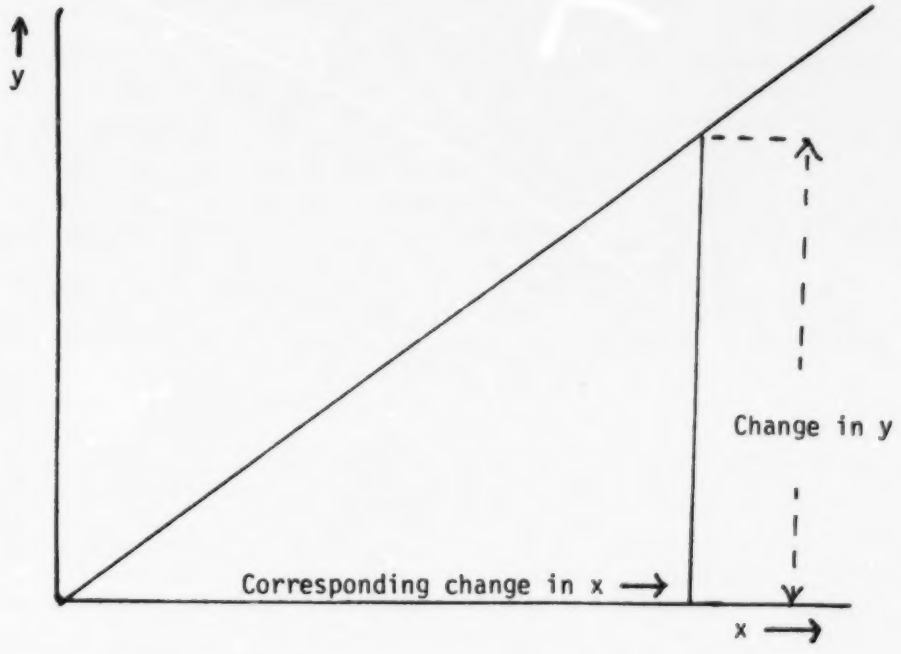
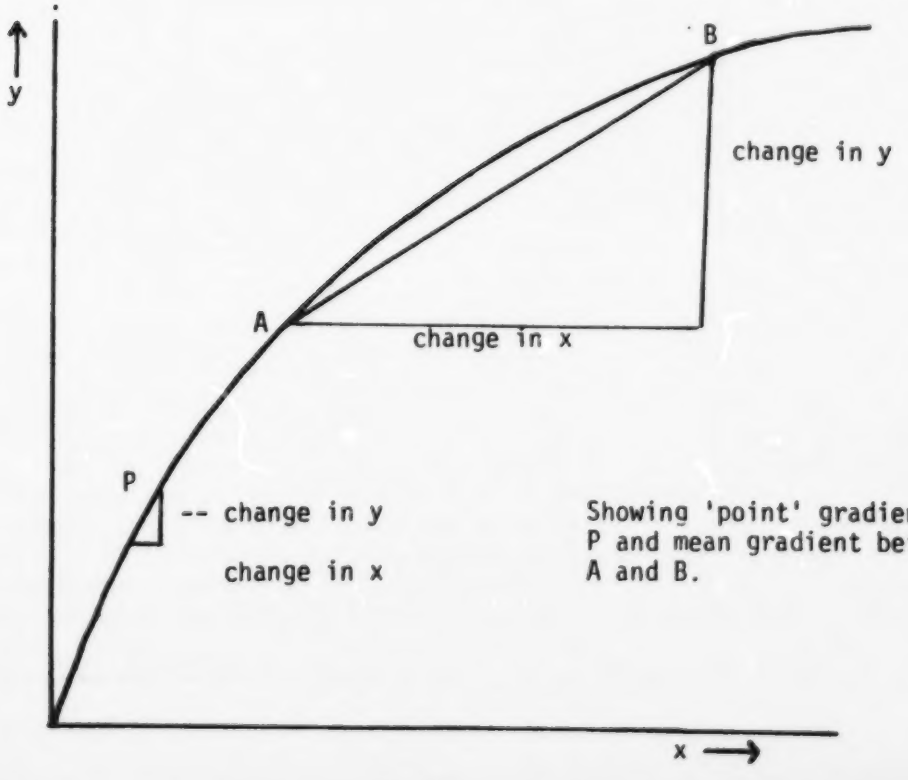


FIGURE 6 - The gradient of a graph



$$\text{Gradient} = \frac{\text{change in y}}{\text{corresponding change in x}}$$



Showing 'point' gradient at P and mean gradient between A and B.

the film-screen combination not to the film alone. The definitions of the parameters of interest are as follows:

Quantity	Definition
Mid gradient	Mean gradient measured between density points 1.0 above base + fog density and 2.0 above base + fog density (ie. between densities of 1.0 net and 2.0 net)
Average gradient	Mean gradient measured between density points 0.25 net (above base + fog) and 2.0 net (above base + fog)
Toe gradient	Mean gradient measured between density points 0.25 net and 1.0 net
Shoulder gradient	Mean gradient measured between density points 2.0 net and 3.0 net
Point gradient	Gradient measured at any specified point

Example - If the B + F density is 0.2, these quantities will be defined as follows:

Mid gradient	Mean gradient measured between density points 1.2 and 2.2
Average gradient	Mean gradient measured between density points 0.45 and 2.2.
Toe gradient	Mean gradient measured between density points 0.45 and 1.2.
Shoulder gradient	Mean gradient measured between density points 2.2 and 3.2.

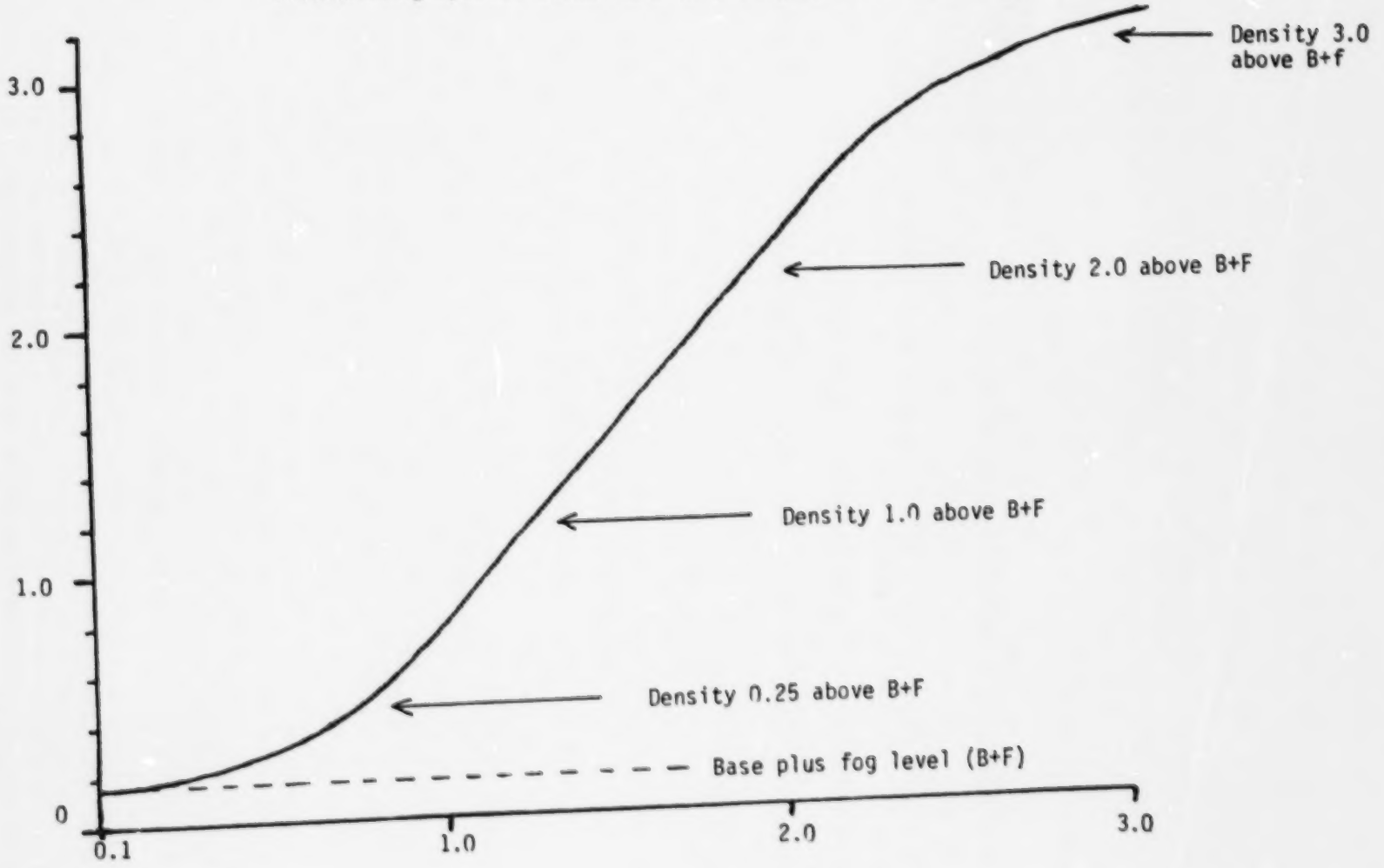
If the density of the exposed film increases rapidly for small increments of exposure, it is referred to in photographic terms as having a "high contrast" emulsion. This clearly applies when the average gradient is high.

A large toe gradient indicates that the film should show detail clearly in relatively low density areas and is desirable when these areas are radiographically important. Similarly, a large shoulder gradient indicates that the film should show detail in relatively high density areas. However, viewing boxes with exceptionally high intensity illumination may be necessary to take advantage of this feature.

The mid-gradient as defined above will usually correspond very closely to the simple concept of the gamma for the straight line portion of the characteristic which was discussed in detail in chapter 8 of this report; and which is one of the parameters the Radiation Safety Unit postal quality assurance program has been designed to evaluate.

FIGURE 6

Illustrating special terms used in photographic sensitometry



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